

# **Variance spectra & moist conserved variables from the A-train**

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# Two Research Thrusts

- **Scale dependence of temperature & water vapor variance**
  - $T(z)$  and  $q(z)$  from **Atmospheric Infrared Sounder (AIRS)** compared to ECMWF
  - Climate model evaluation [and parameterization improvement]
- **Calculation of  $\theta_e$ ,  $\theta_l$  &  $q_t$** 
  - Combination of coincident AIRS & CloudSat (LWC) profiles
  - Morphology, seasonality [and comparisons to models]



# Aircraft-derived Mesoscale Spectra – $u, v, \theta$

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G. D. NASTROM AND K. S. GAGE

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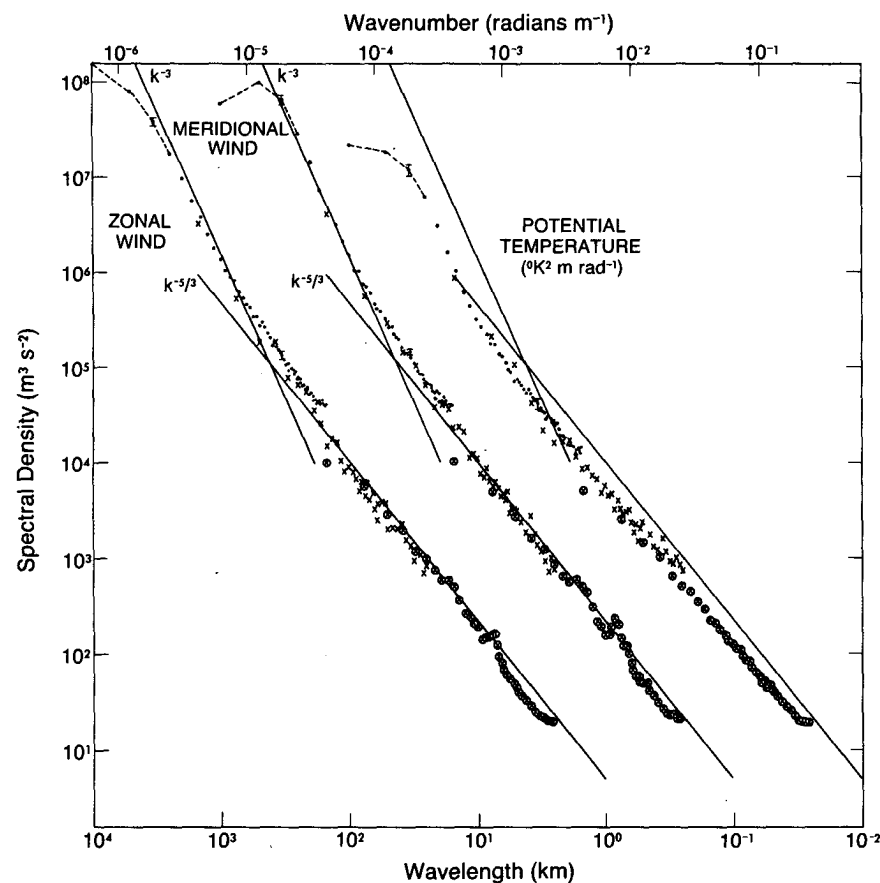
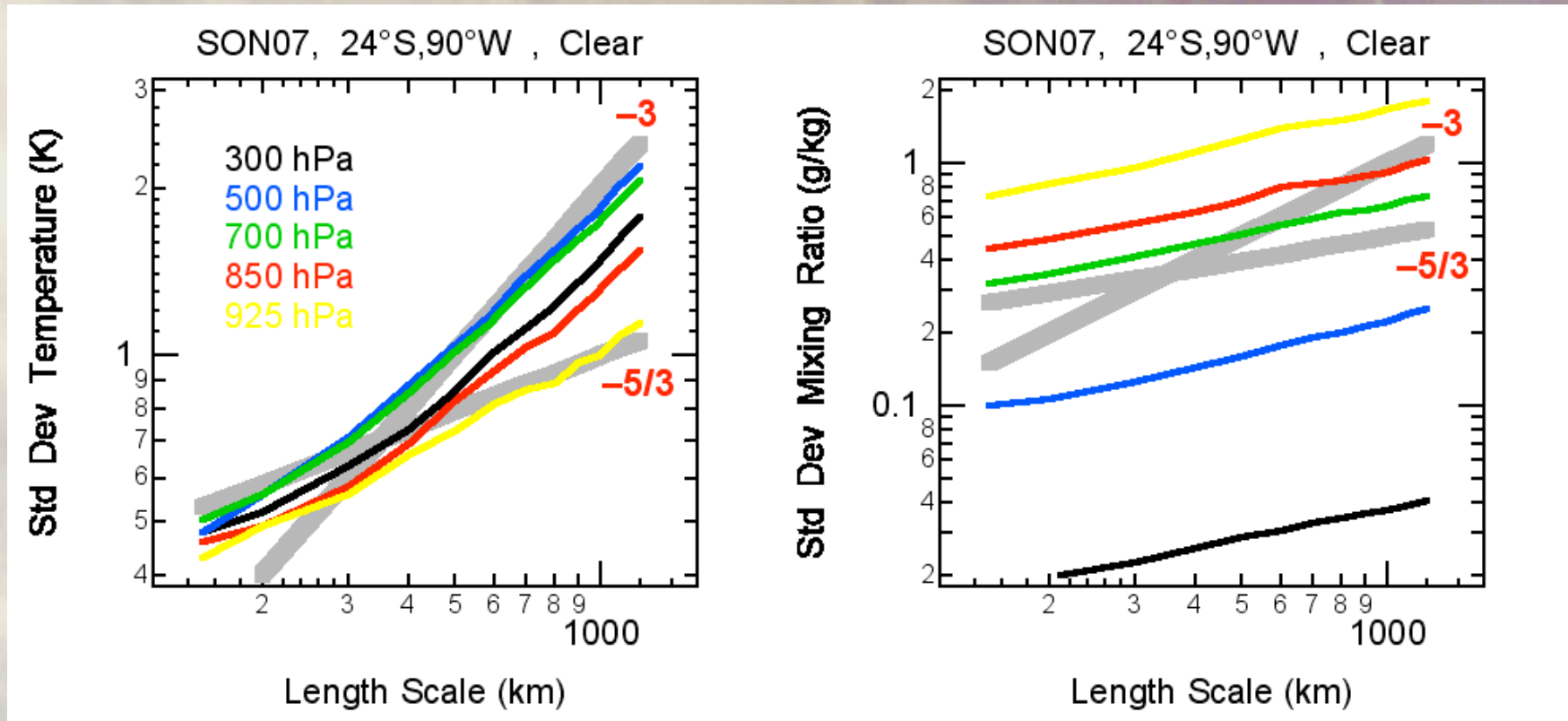


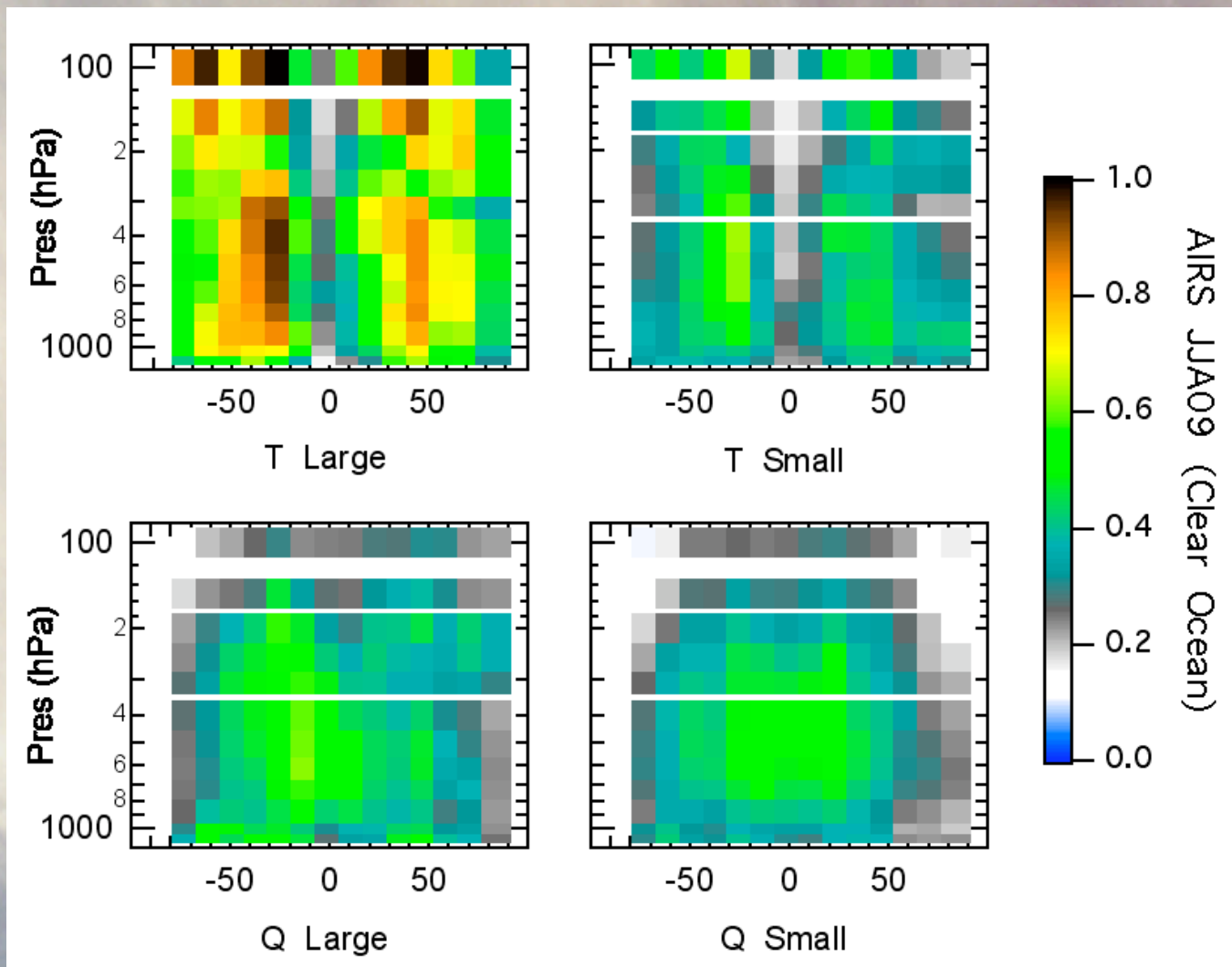
FIG. 3. Variance power spectra of wind and potential temperature near the tropopause from GASP aircraft data. The spectra for meridional wind and temperature are shifted one and two decades to the right, respectively; lines with slopes  $-3$  and  $-5/3$  are entered at the same relative coordinates for each variable for comparison.

# Scaling exponents & breaks observed with AIRS

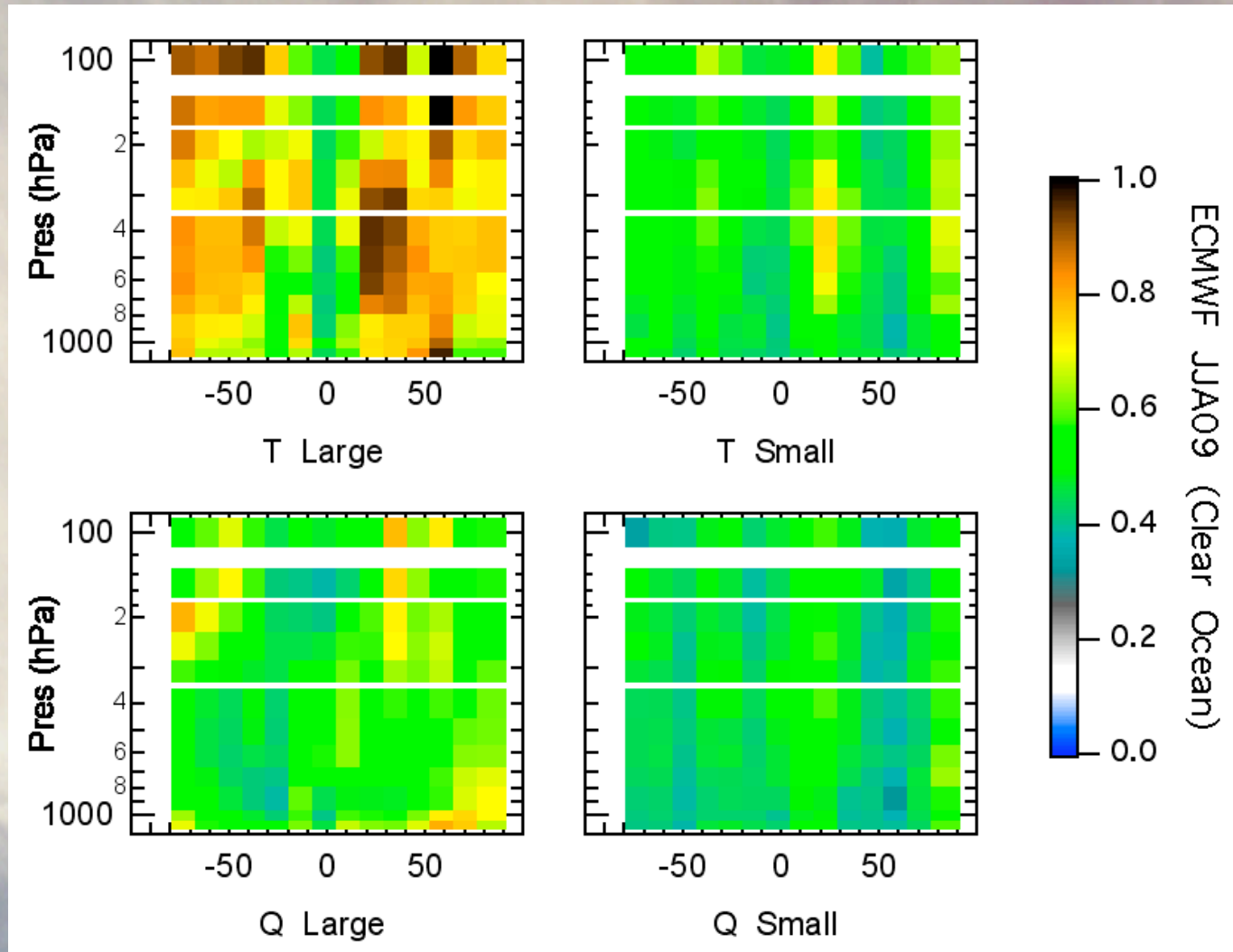


Variance scaling/structure function exponents of 1.0, 0.5 and  $0.33 \approx -3, -2$ , and  $-5/3$ , respectively

# Mesoscale break for $T$ – not for $Q$ – in AIRS

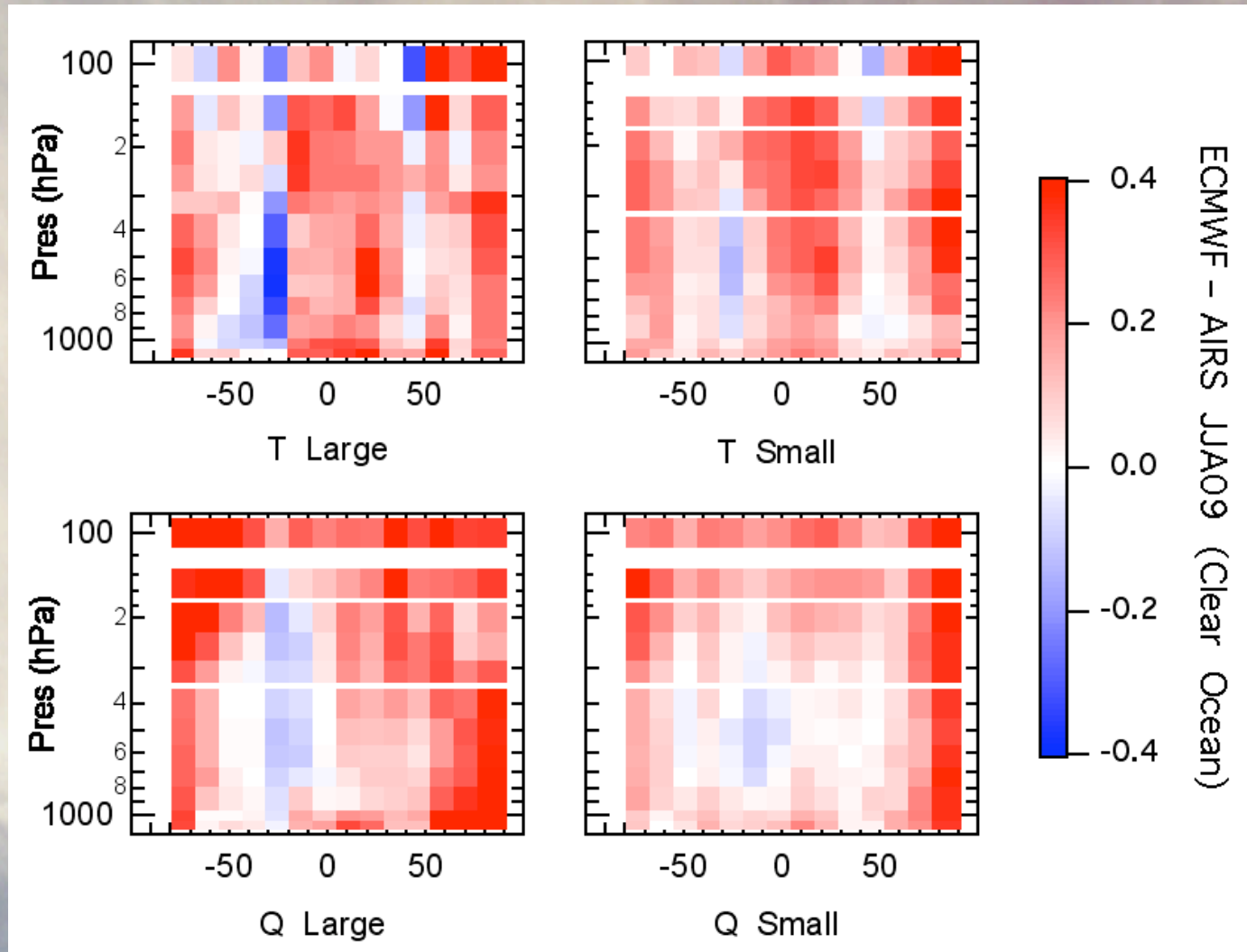


# Overall larger exponents in ECMWF

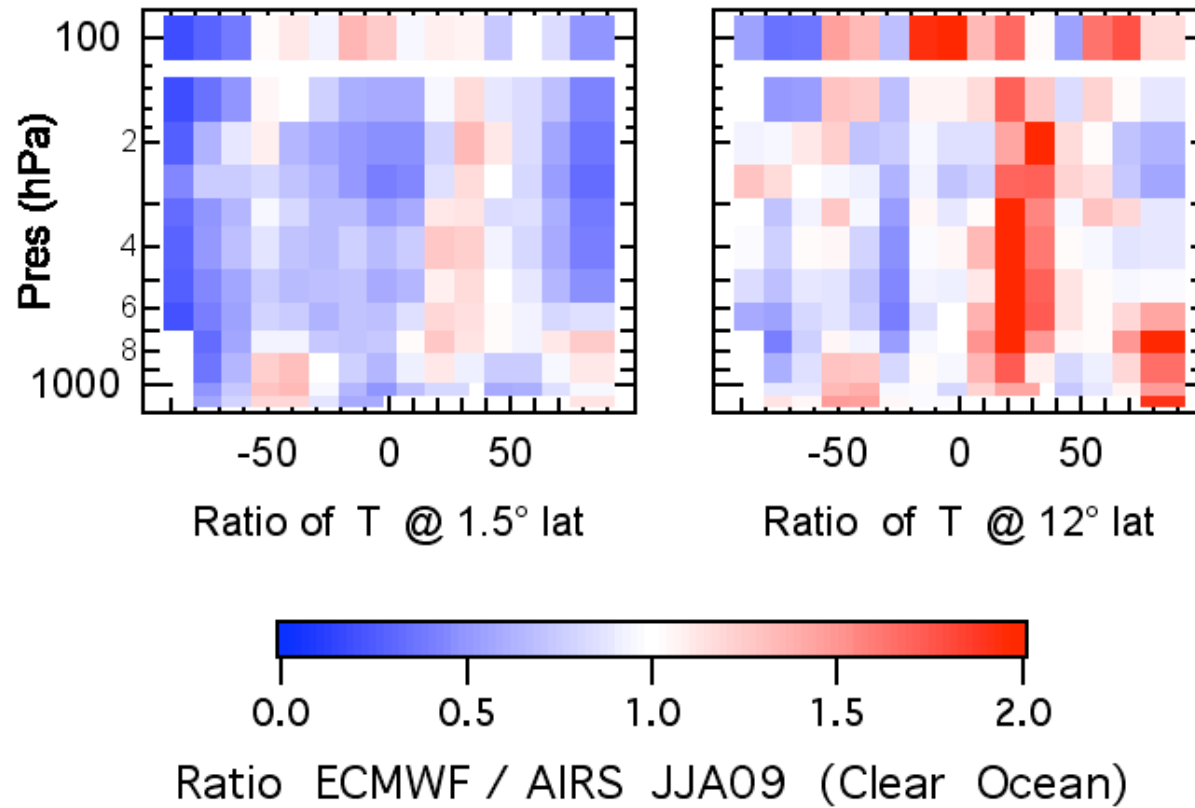




# ECMWF – AIRS Exponents

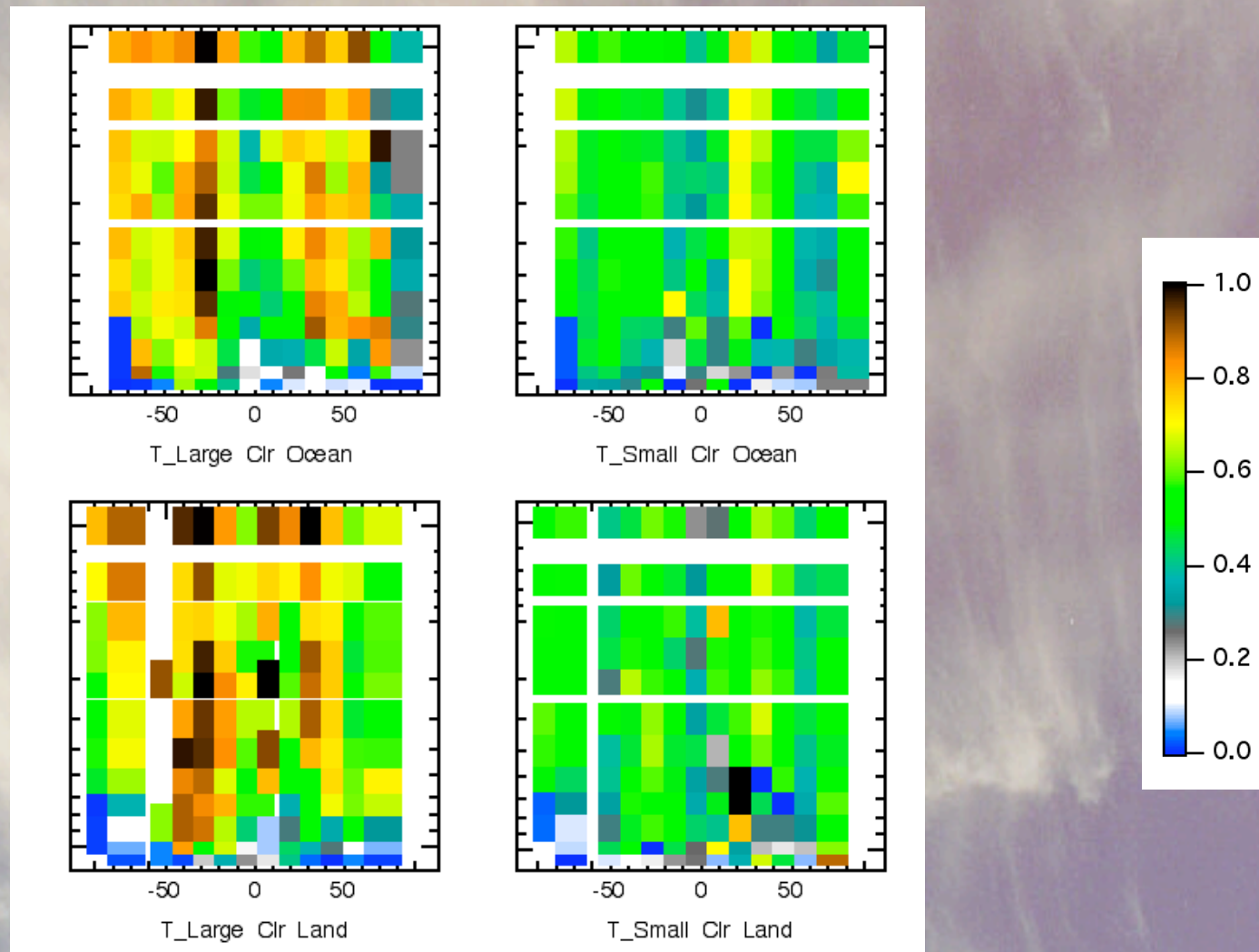


# ECMWF variance at small scales too small

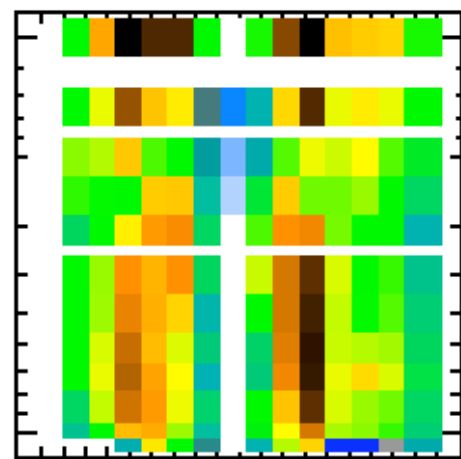




# GFDL Similar to ECMWF (preliminary)

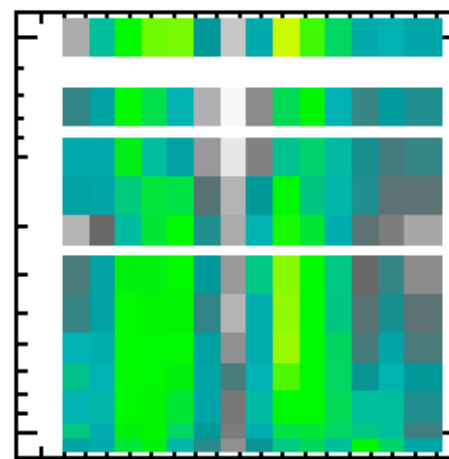


# 7 Years of AIRS – DJF '03 Clear Sky $T(z)$



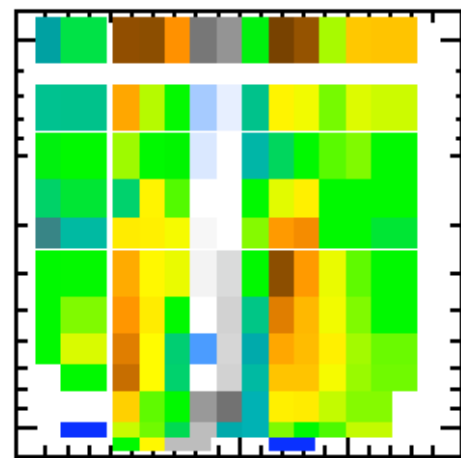
-50 0 50

T\_Large Clr Ocean



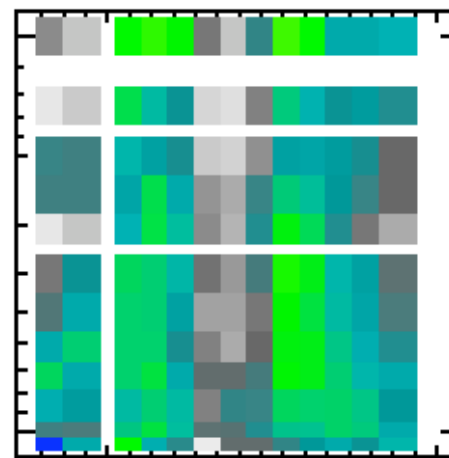
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T\_Small Clr Ocean



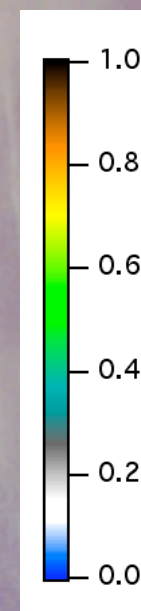
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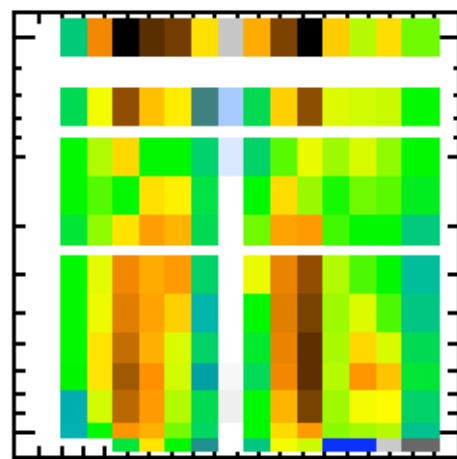


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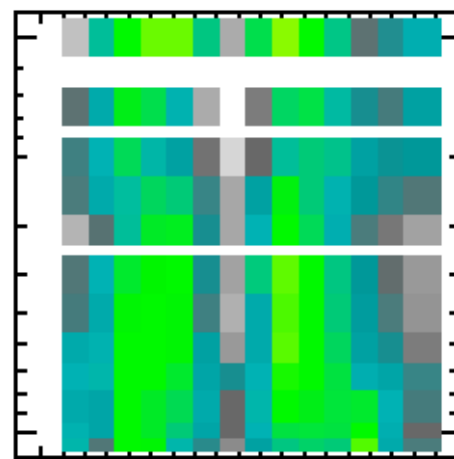
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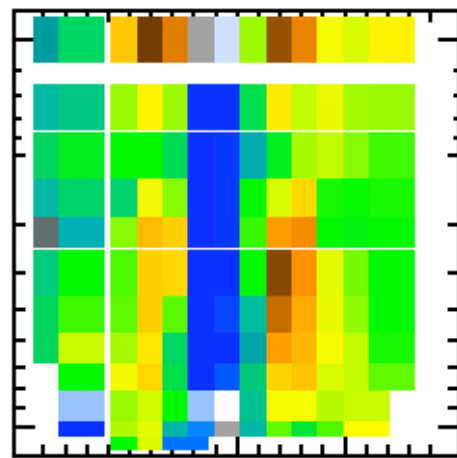
# 7 Years of AIRS – DJF '04 Clear Sky $T(z)$



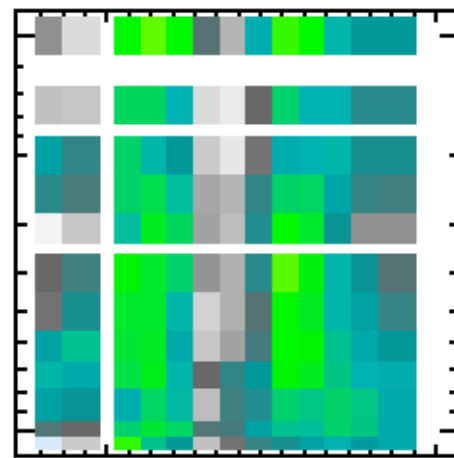
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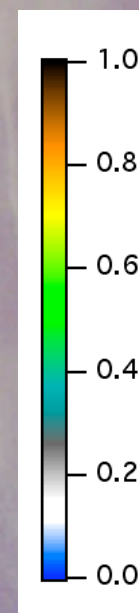
T\_Small Clr Ocean



T\_Large Clr Land

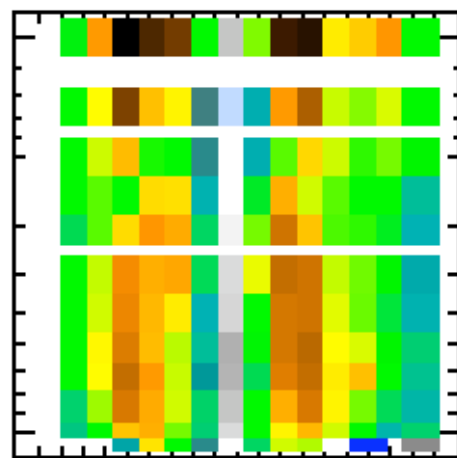


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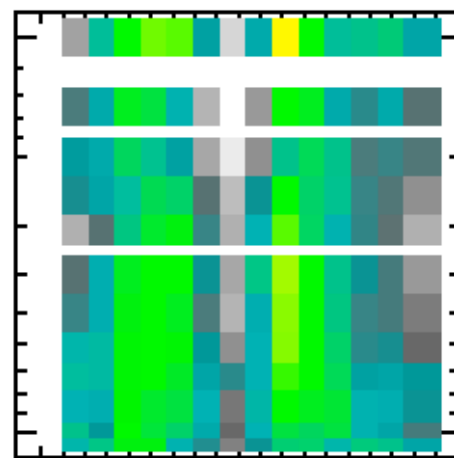


# 7 Years of AIRS – DJF '05 Clear Sky $T(z)$



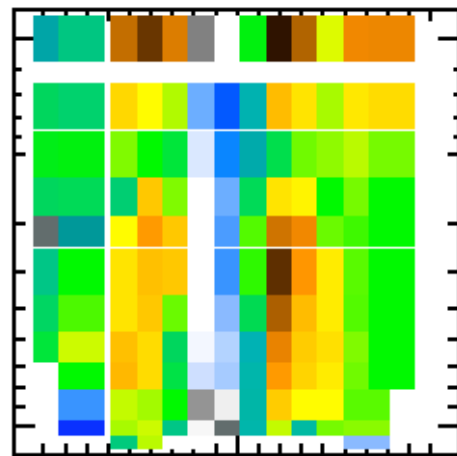
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T\_Large Clr Ocean



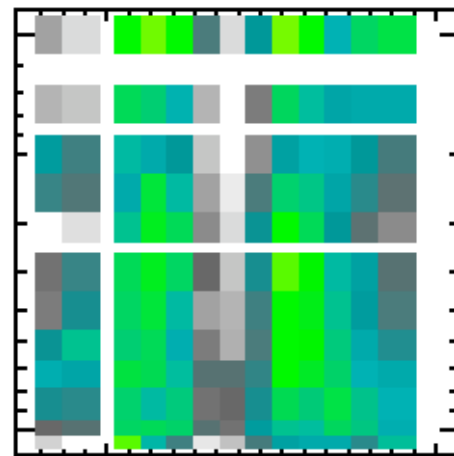
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T\_Small Clr Ocean



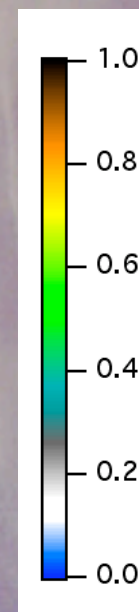
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T\_Large Clr Land

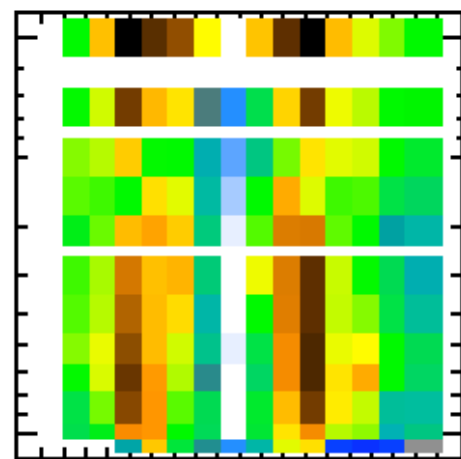


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T\_Small Clr Land

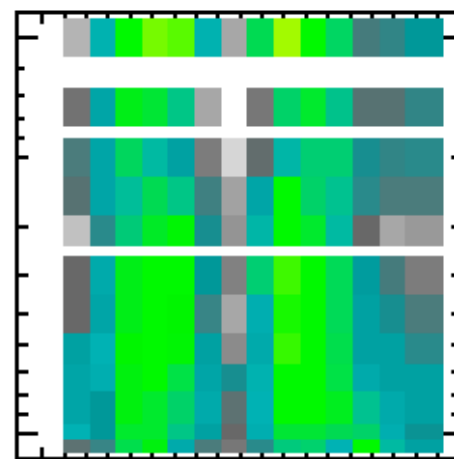


# 7 Years of AIRS – DJF '06 Clear Sky $T(z)$



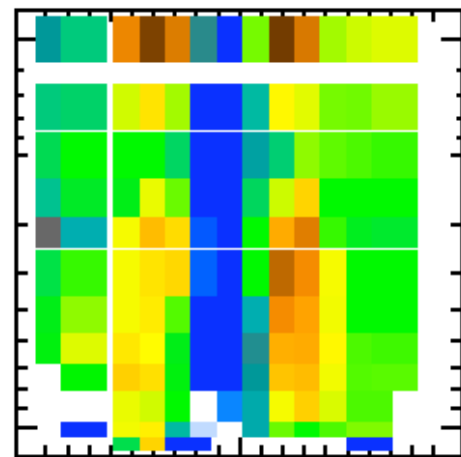
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T\_Large Clr Ocean



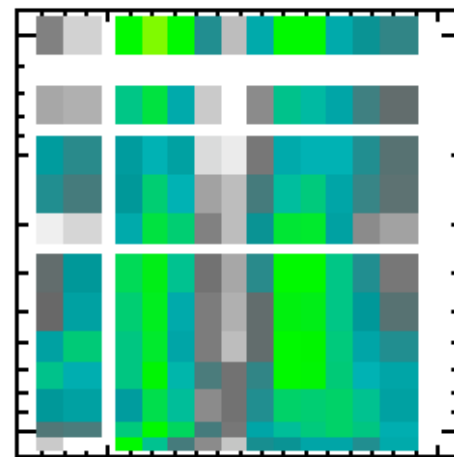
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T\_Small Clr Ocean



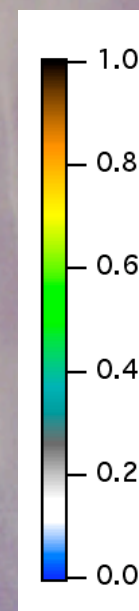
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T\_Large Clr Land

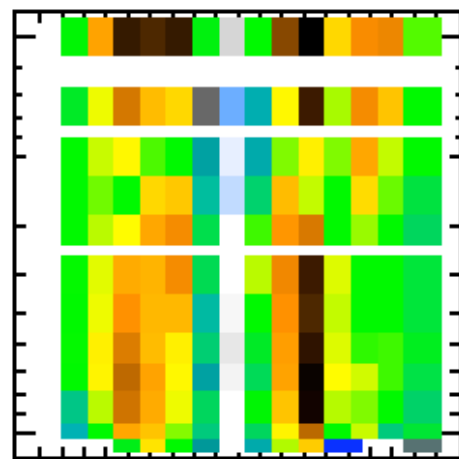


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T\_Small Clr Land

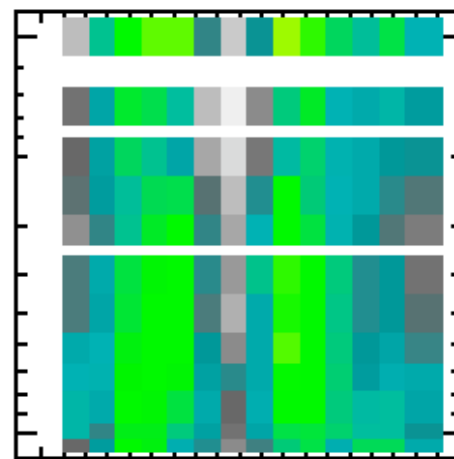


# 7 Years of AIRS – DJF '07 Clear Sky $T(z)$



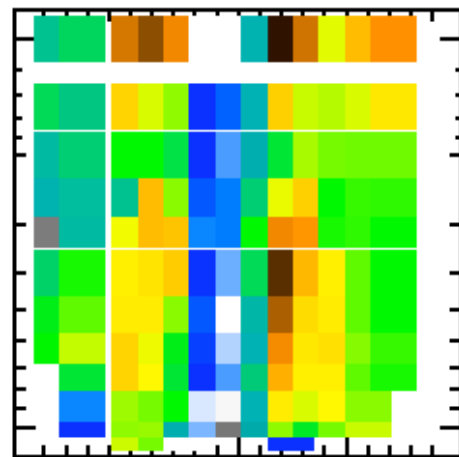
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T\_Large Clr Ocean



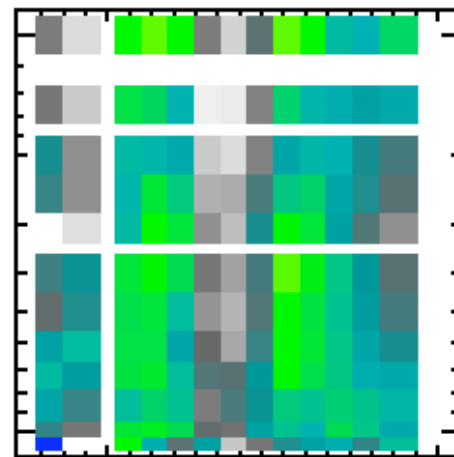
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T\_Small Clr Ocean



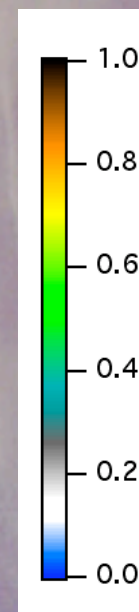
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T\_Large Clr Land



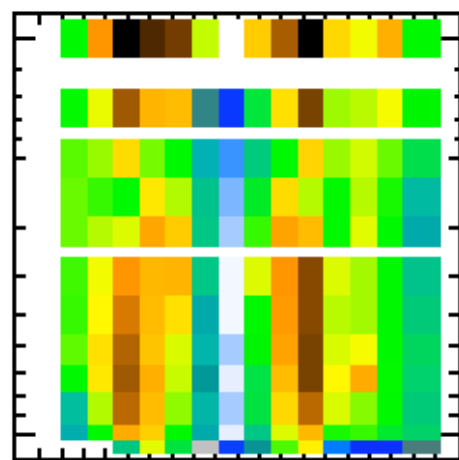
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T\_Small Clr Land

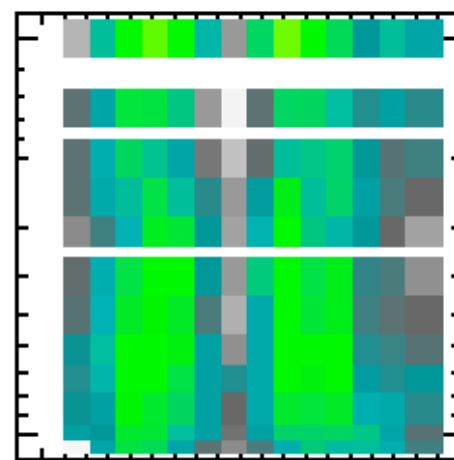




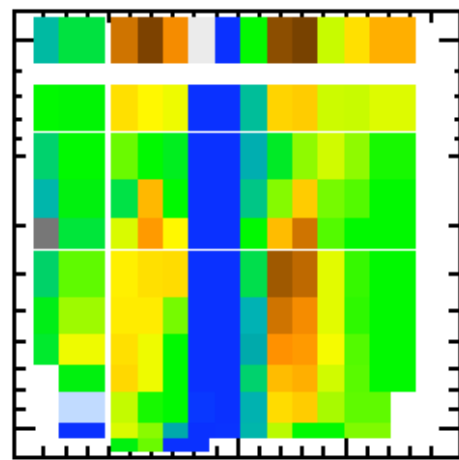
# 7 Years of AIRS – DJF '08 Clear Sky $T(z)$



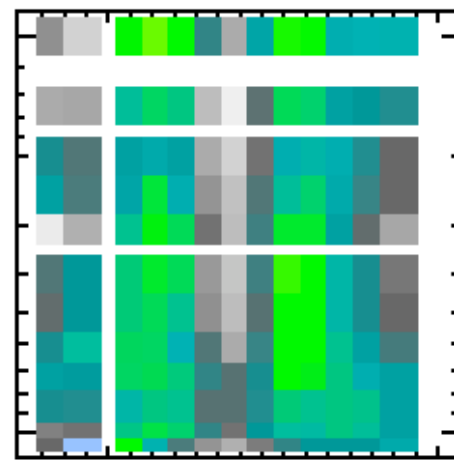
T\_Large Clr Ocean



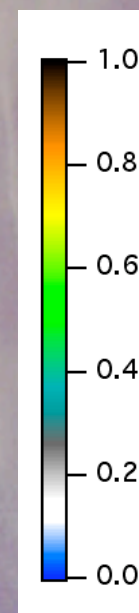
T\_Small Clr Ocean



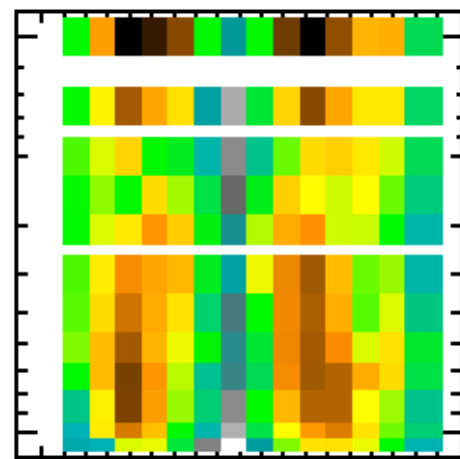
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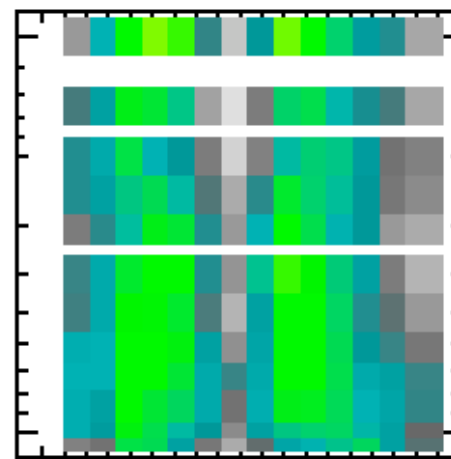
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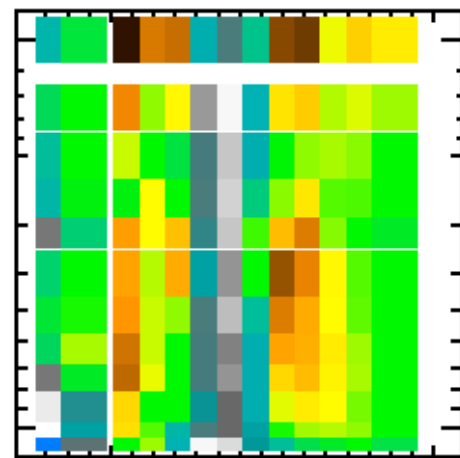
# 7 Years of AIRS – DJF '09 Clear Sky $T(z)$



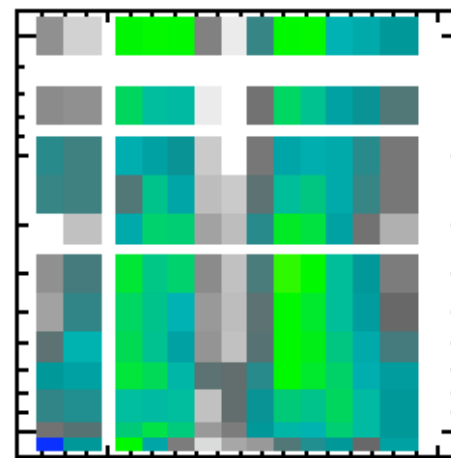
T\_Large Clr Ocean



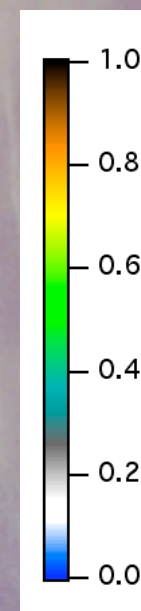
T\_Small Clr Ocean



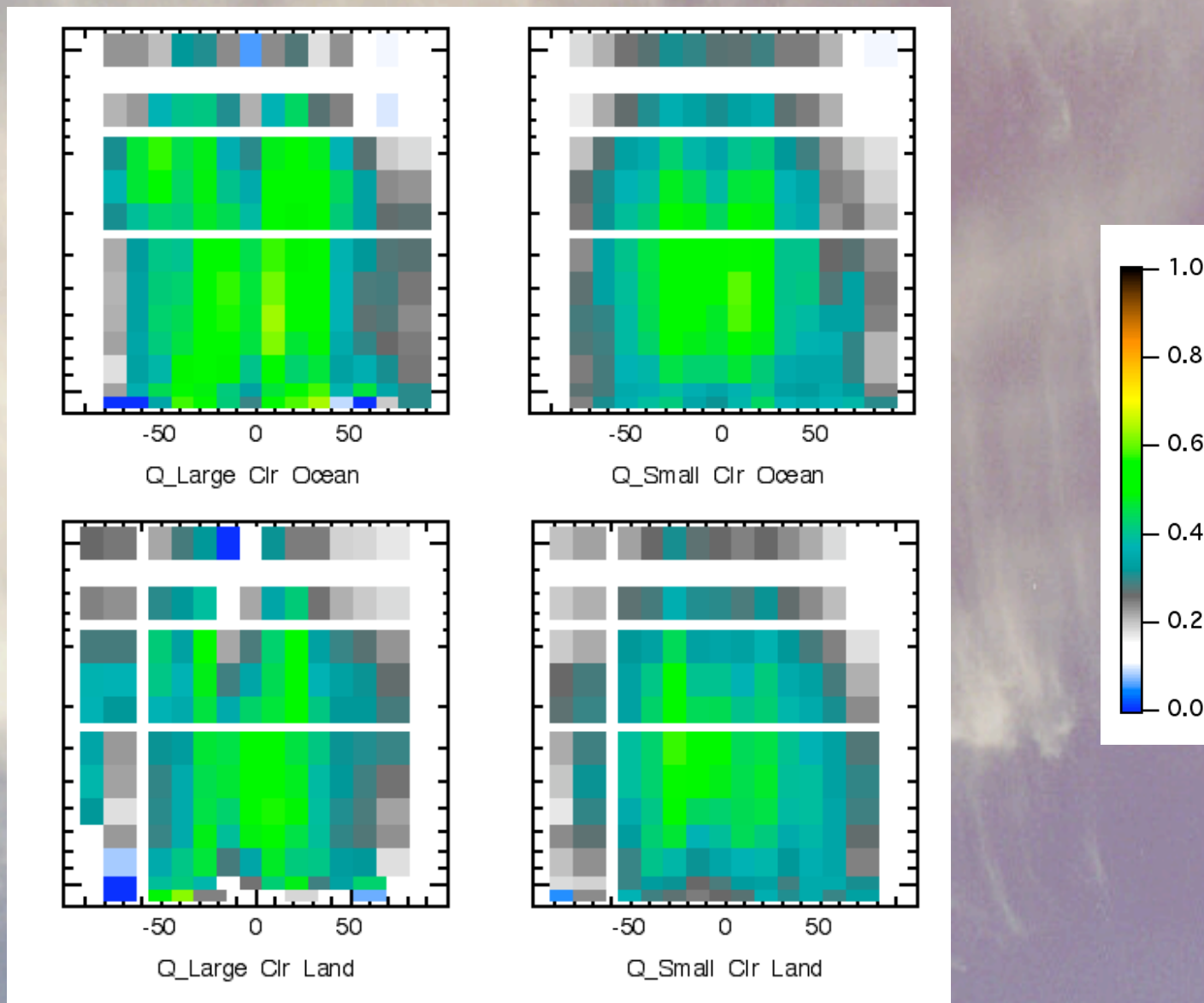
T\_Large Clr Land



T\_Small Clr Land

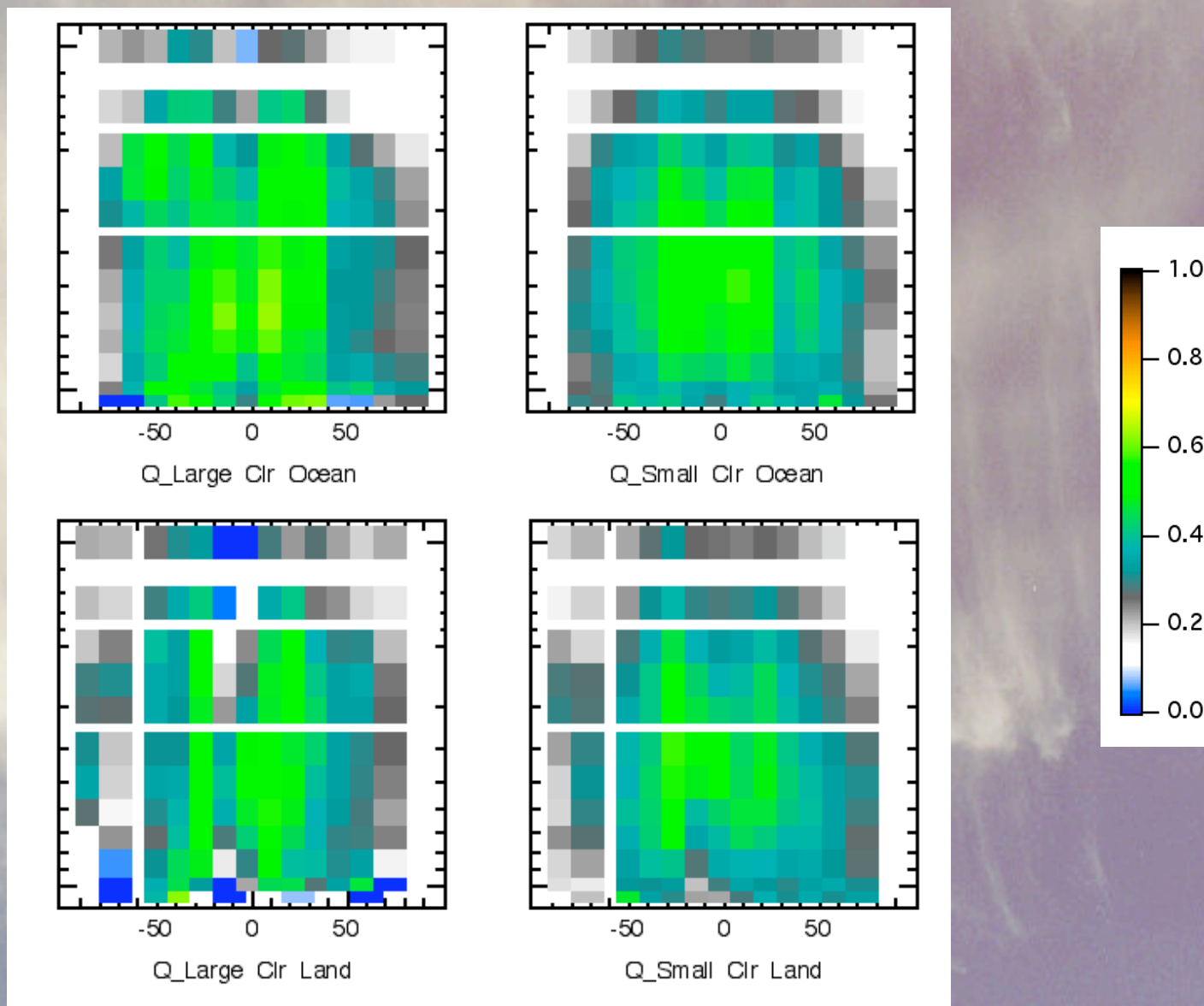


# 7 Years of AIRS – DJF '03 Clear Sky $q(z)$

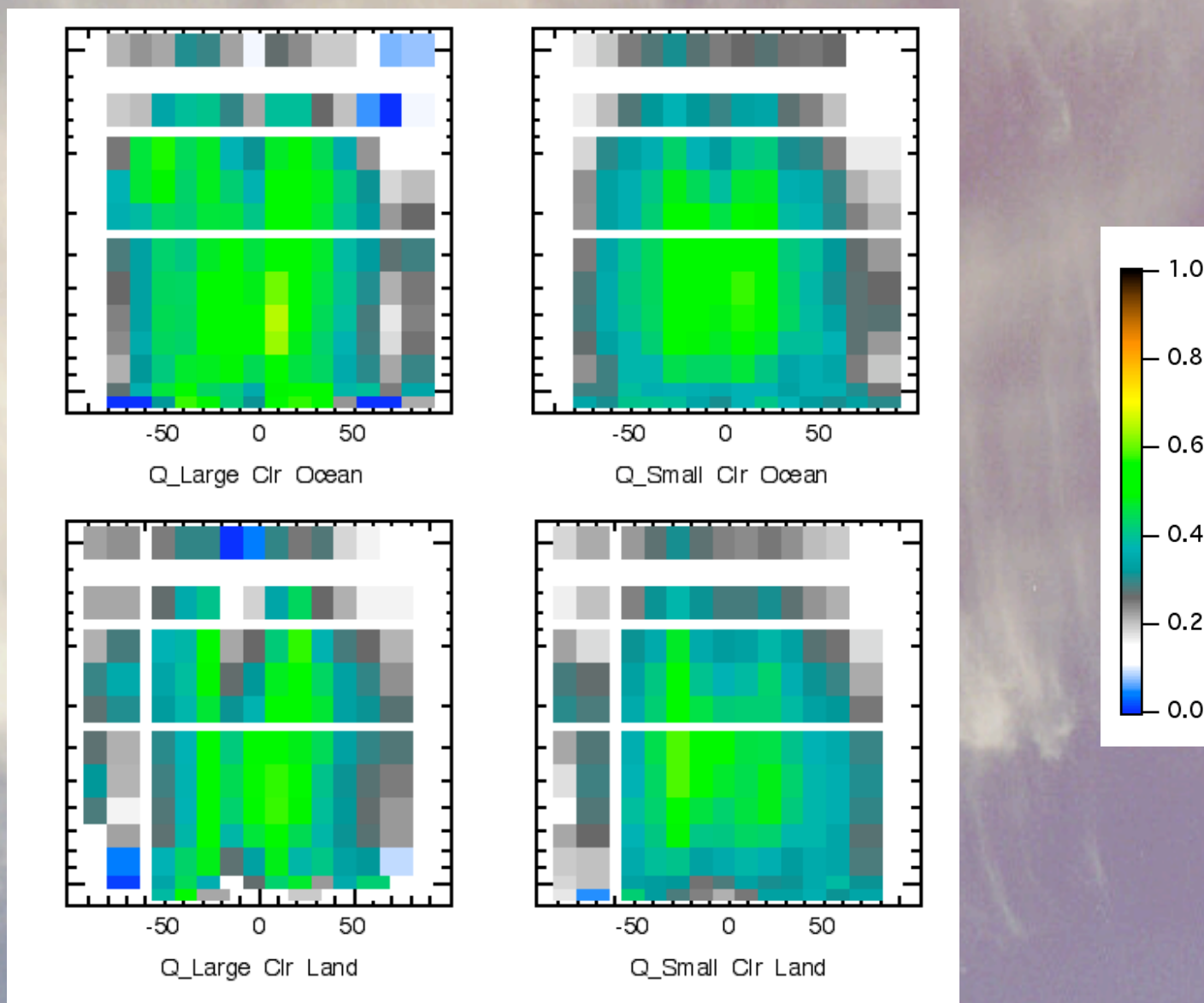




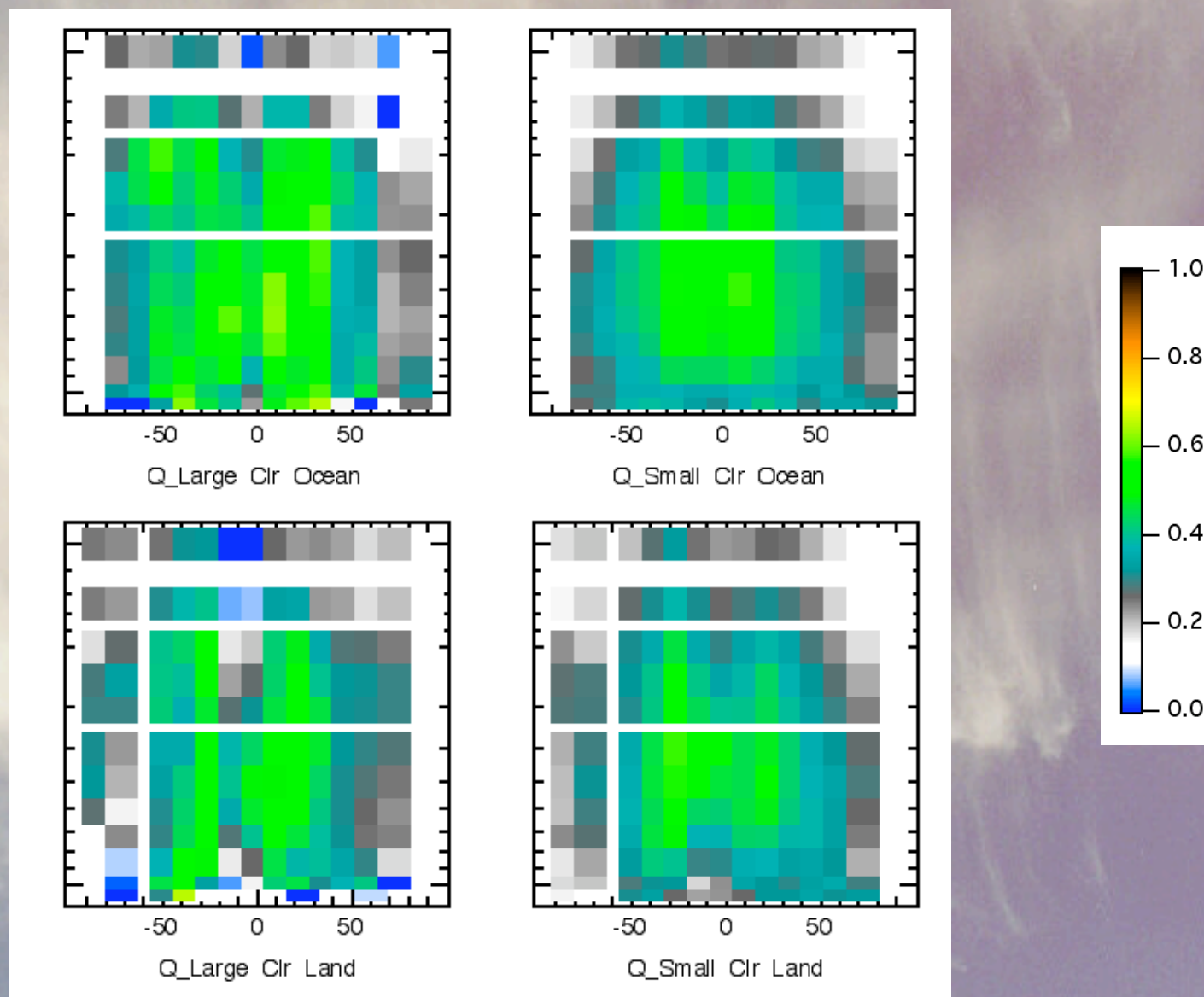
# 7 Years of AIRS – DJF '04 Clear Sky $q(z)$



# 7 Years of AIRS – DJF '05 Clear Sky $q(z)$

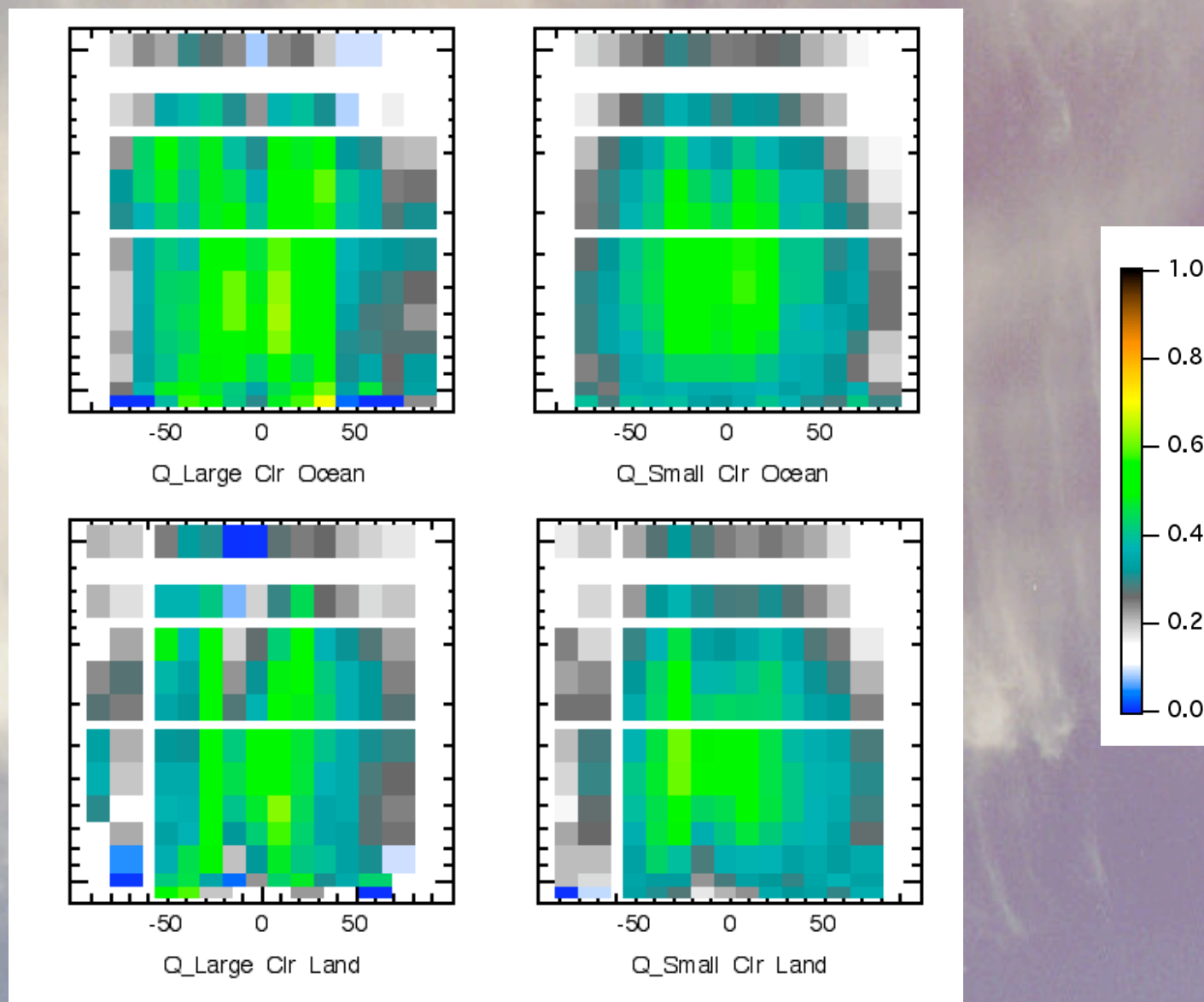


# 7 Years of AIRS – DJF '06 Clear Sky $q(z)$

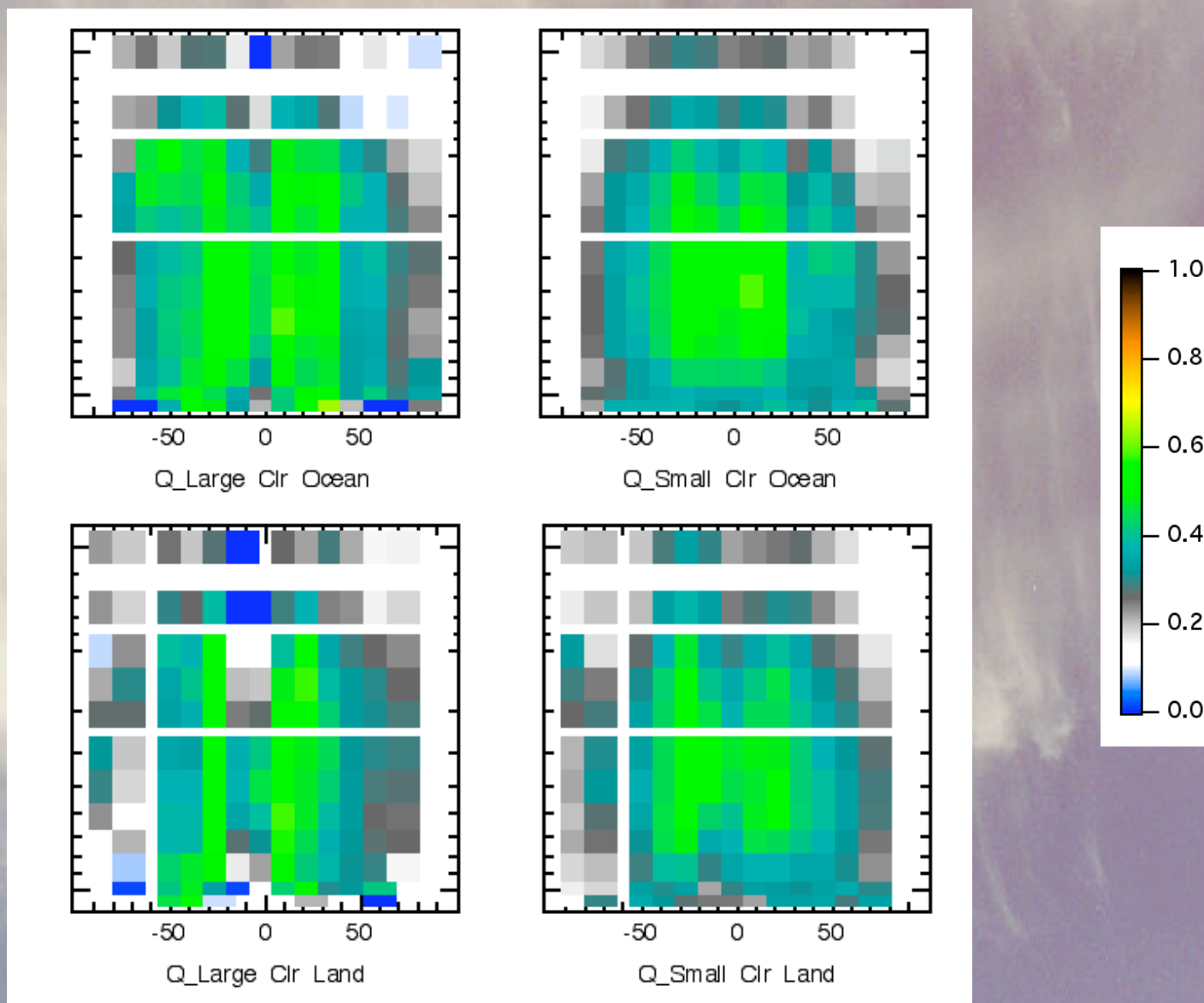




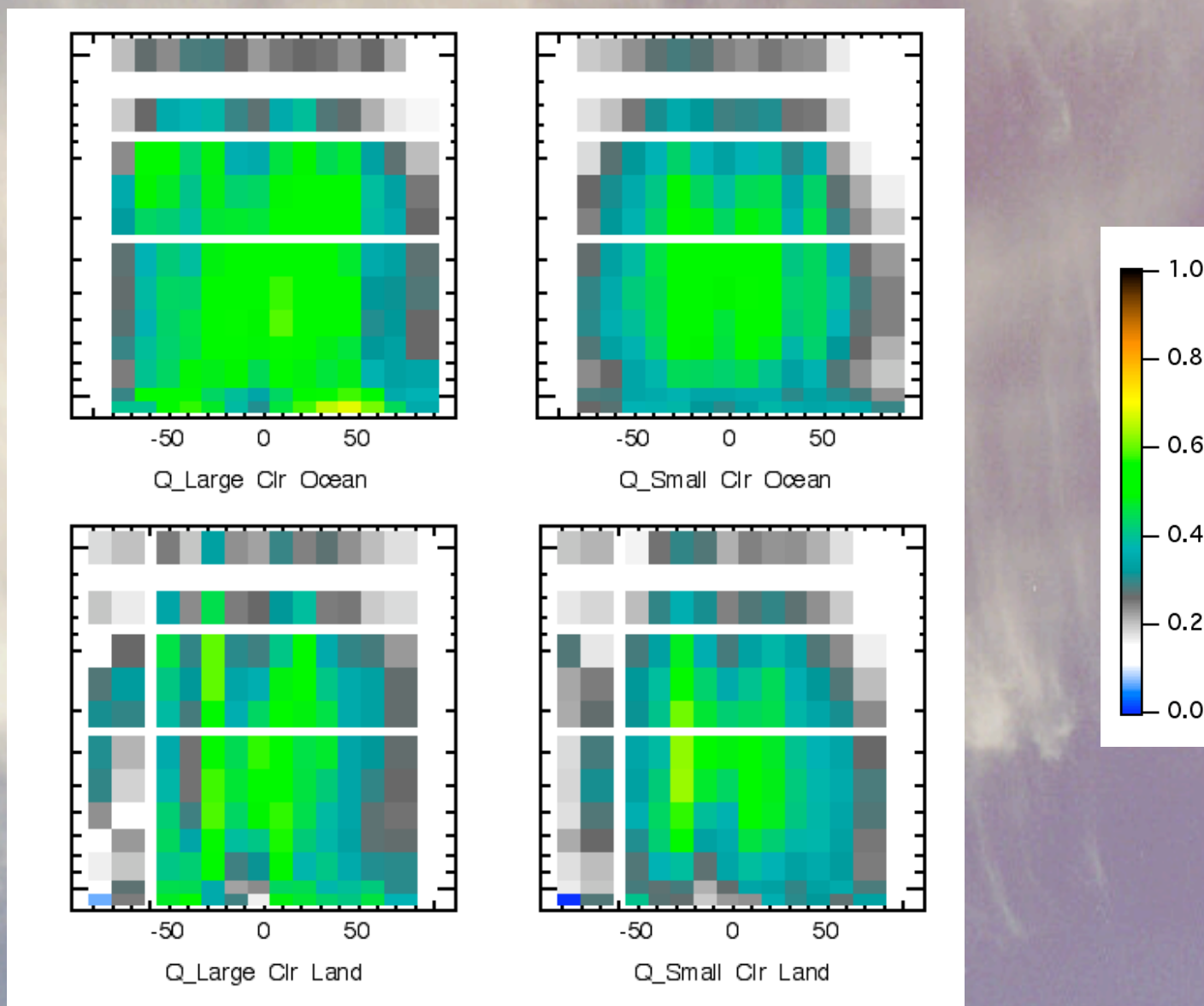
# 7 Years of AIRS – DJF '07 Clear Sky $q(z)$



# 7 Years of AIRS – DJF '08 Clear Sky $q(z)$



# 7 Years of AIRS – DJF '09 Clear Sky $q(z)$





# Moist conserved variables: AIRS & CloudSat

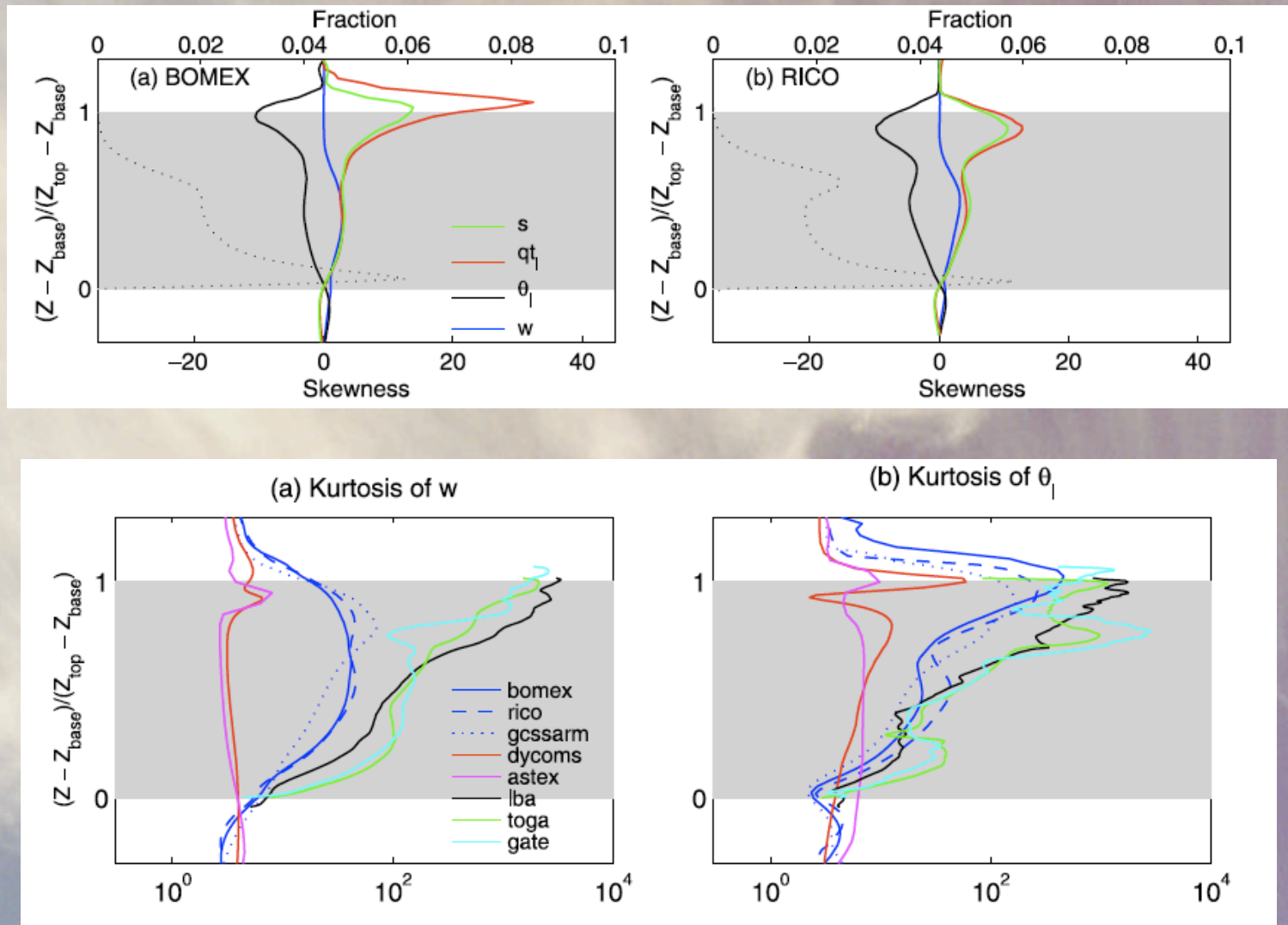
- **Temperature and water vapor profiles from AIRS**
  - “Best” quality Standard Product retrievals  $\pm 25^\circ$  [trade wind Cu regime]
- **LWC profiles from CloudSat**
  - Flagged out precipitating clouds
- **Smooth LWC to AIRS vertical & horizontal resolution**
  - Could go to smaller scales, but more complicated & requires assumptions

- **AIRS only:** 
$$\theta_e = \left( T + \frac{L_v}{c_p} r_v \right) \left( \frac{p_0}{p} \right)^{R_d/c_p}$$

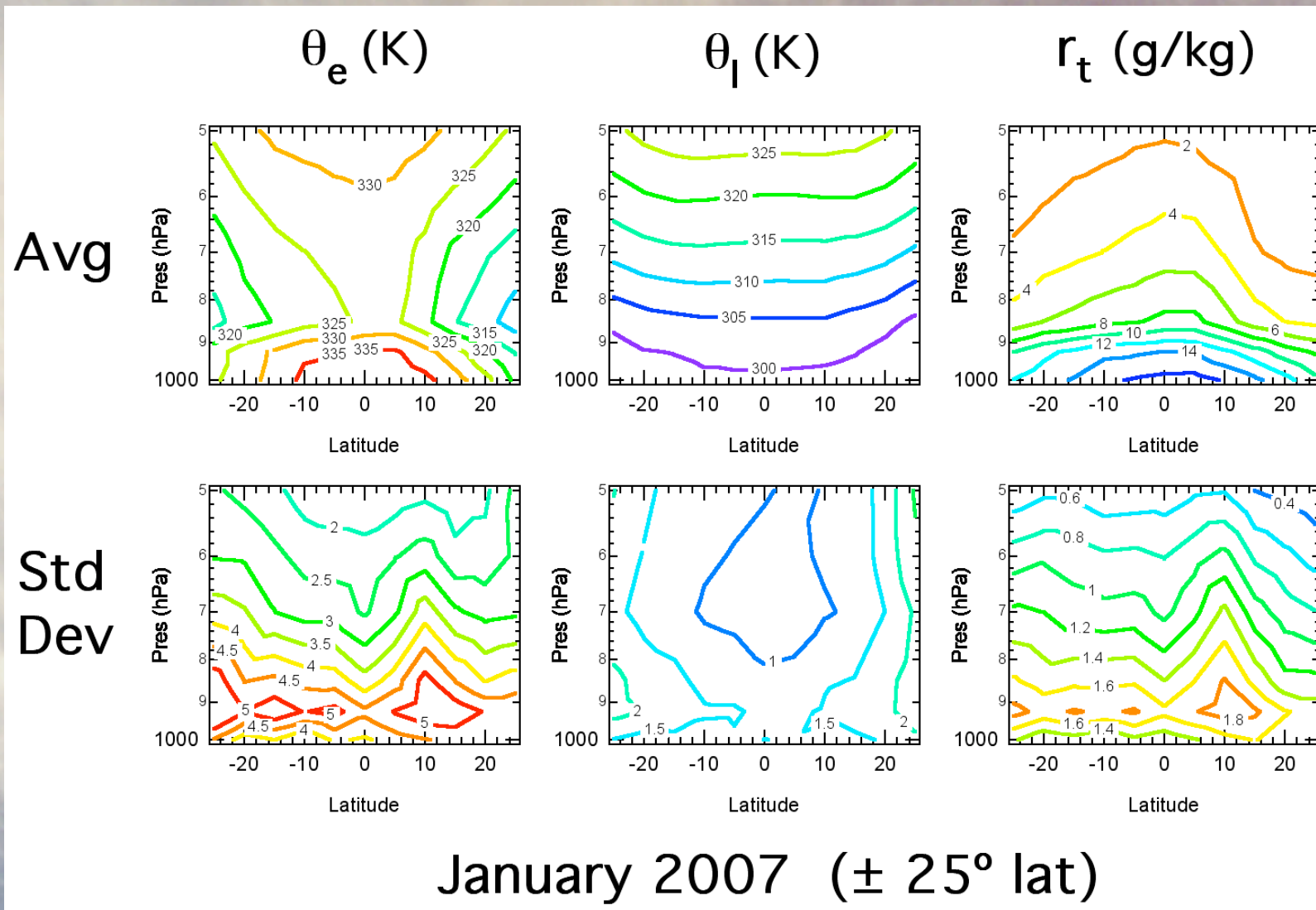
- **AIRS + CloudSat:** 
$$\theta_l \approx \theta - \frac{L_v}{c_{pd}} r_l \qquad r_t = r_v + r_l$$



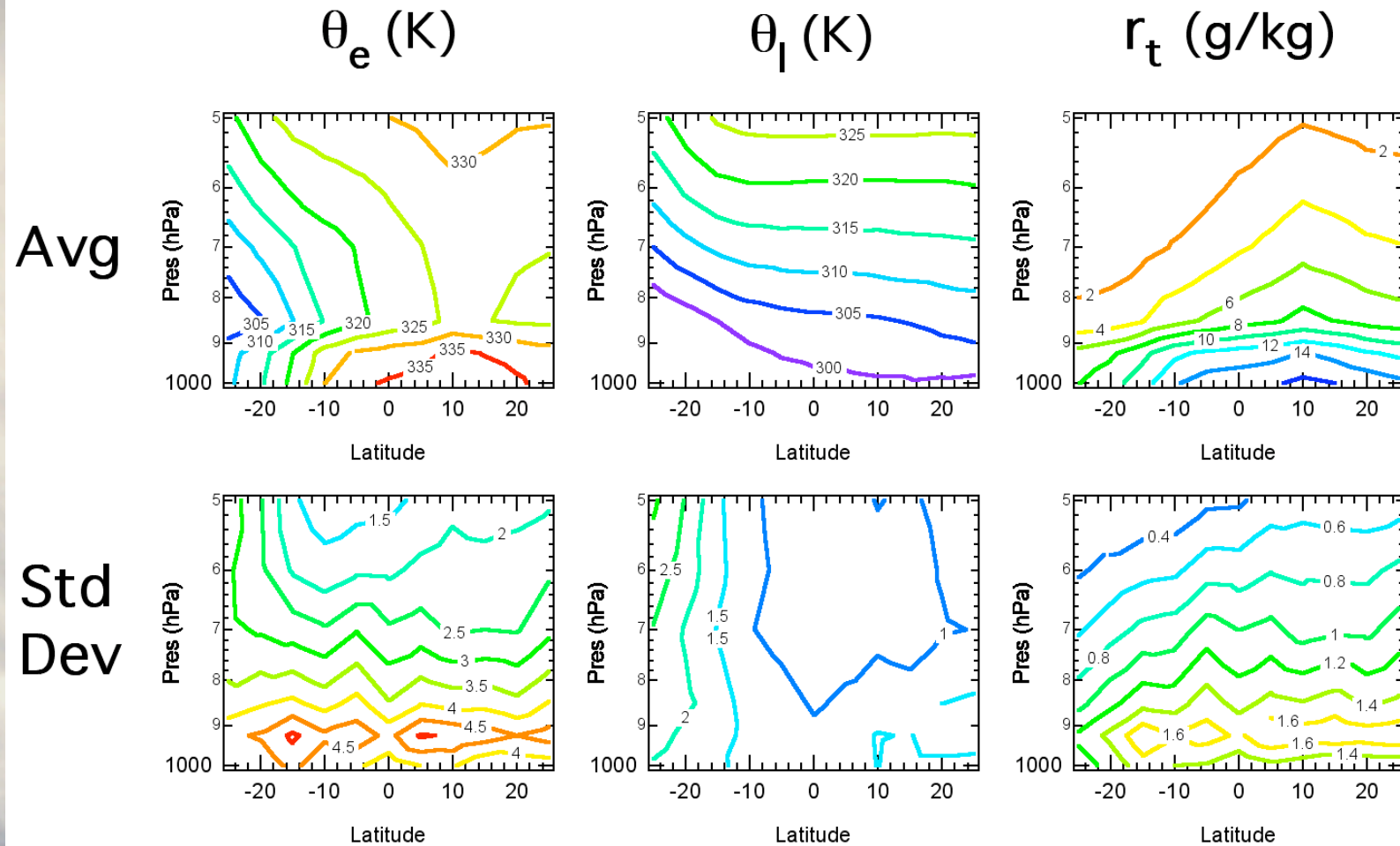
# Cloud-resolving model results for shallow Cu



# Zonal and altitude variations consistent with expectations

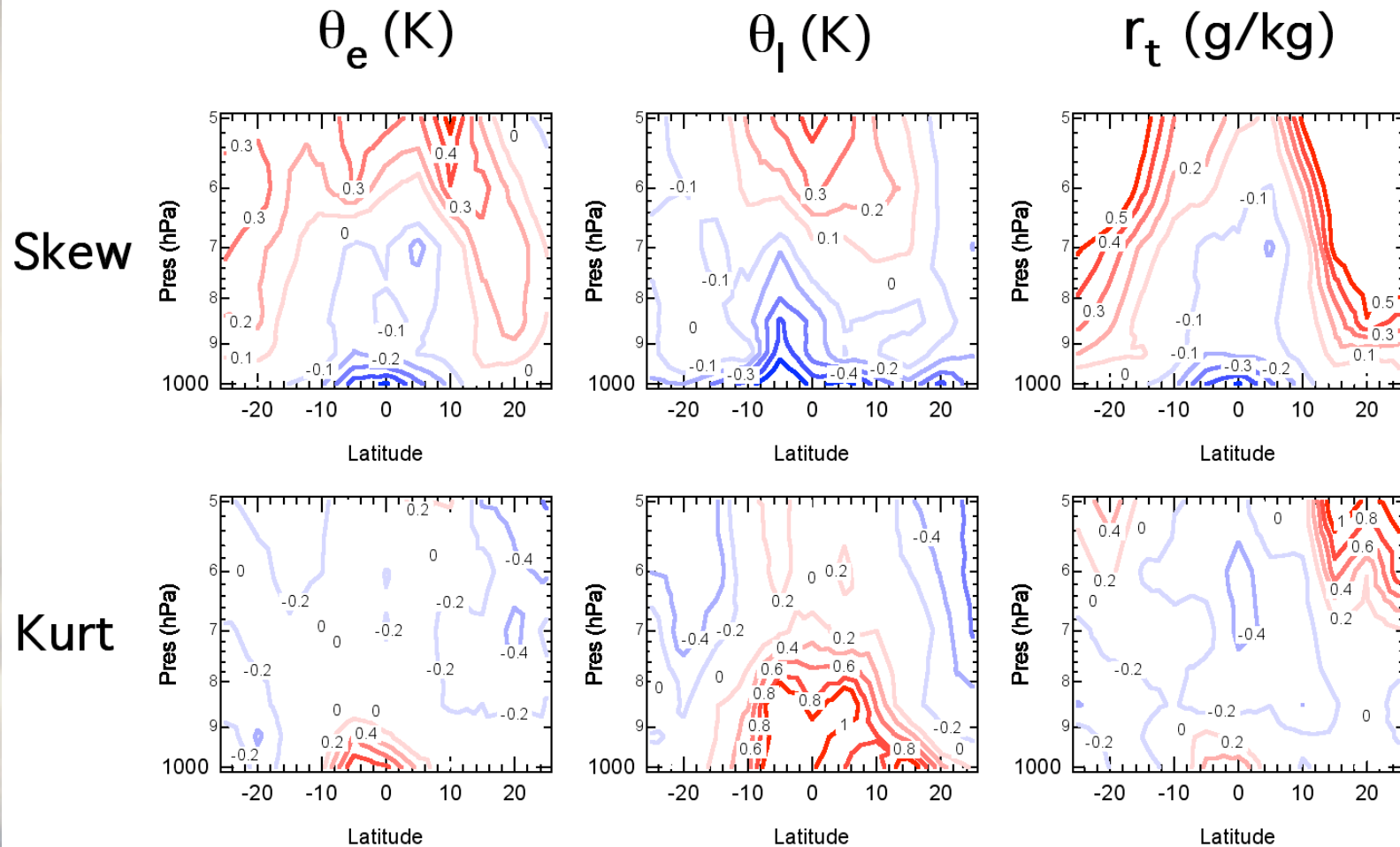


# Seasonal variations in magnitude and latitudinal migration



July 2007 ( $\pm 25^\circ$  lat)

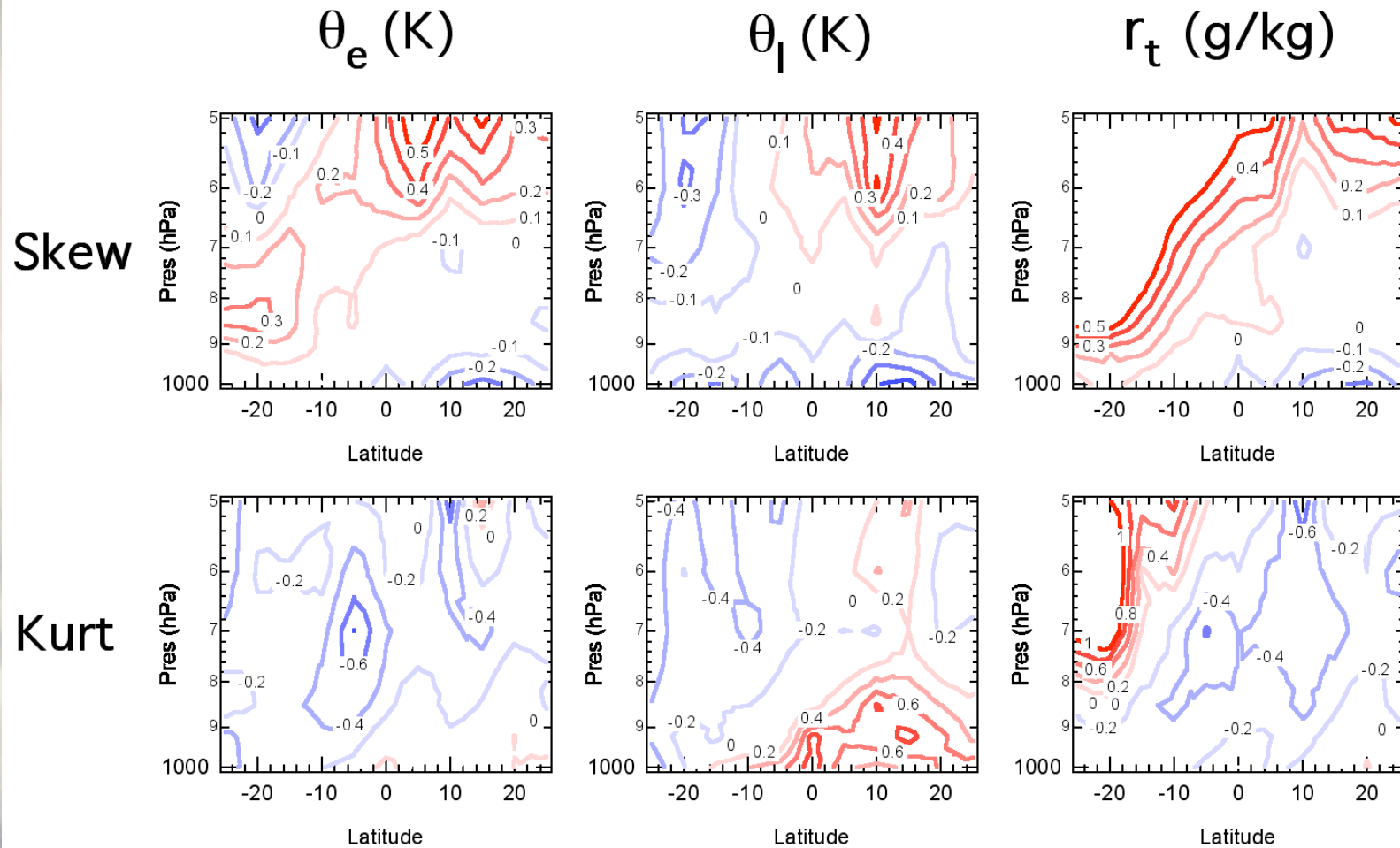
# Significant zonal and altitude variations in skewness and kurtosis



January 2007 ( $\pm 25^\circ$  lat)



# Seasonal variations in magnitude and patterns of skewness and kurtosis



July 2007 ( $\pm 25^\circ$  lat)

# Take Home Messages

- **AIRS variance scaling reveals rich structure in  $T(z)$  and  $q(z)$** 
  - Kahn et al. (2009), *J. Climate*
- **Comparisons of AIRS and ECMWF**
  - Latitude/altitude patterns somewhat similar
  - ECMWF exponents larger than AIRS
    - ECMWF small-scale variability less than AIRS
- **Moist conserved variables from AIRS+CloudSat**
  - Variability, skewness, kurtosis dependent on variable, altitude, latitude
- **Combined A-train data sets offer new global insights**
  - Scale-dependent variability – is the “turbulence” right in climate models?
  - New quantities obtained from multi-sensor observations